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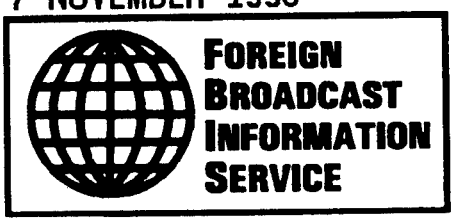

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ATOMIC ENERGY SOCIETY FALL MEETING

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ATOMIC ENERGY SOCIETY FALL MEETING

906C0038 Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese
Sep 89 pp 1-30, 282

[Selected papers presented at the 1989 Fall Meeting of the Atomic Energy Society of Japan held 17-19 Oct 89 in Tokyo; special topic: "Various Issues Regarding Cold Fusion"]

CONTENTS

Detection of Electrolysis-Induced Neutrons

906C0038A Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 1-2

[Article by Shigeyasu Sakamoto, Tokaidai University: "Detection of Room Temperature Fusion Neutrons"]

[Text] **Introduction**

At the end of this March, Professors Fleischmann and Pons reported that they had succeeded in room temperature fusion based on the electric decomposition of heavy water. Soon after, Dr Jones and his group reported their own experimental results of room temperature fusion, which attracted public attention and triggered supplementary examination by interested researchers both domestic and abroad in an effort to define room temperature fusion.

The author has conducted supplementary experiments on the electrolytic method, in which palladium is used as a cathode, to confirm the possibility of room temperature fusion in terms of neutron measurement. The experimental results are reported below:

Experimental Device and Measurement

We used an electrolytic bath with a content volume of 2 cc for our experiment, in which palladium wire was used as a cathode and a white metal wire of the same size was used as an anode, and electrolysis was carried out inside a calorimeter. For the experiment, we used an electrolyte produced by adding 3 percent by weight NaOH to heavy water having a purity of 99.85 percent, and carried out electrolysis, passive electric currents ranging from 10~20 mA (the electric density at the cathode ranged from 140~320 mA/cm^2) from a constant voltage source. Figure 1 shows a sectional view of the electrolytic bath used in our experiment.

To detect neutrons, we used a slowing down type fast neutron detector with a 5 cm thick paraffin cylinder mounted on BF_3, and obtained a detection efficiency of 1.4×10^{-3} corrected by a Cf-252 neutron source. To reduce the background counting (hereafter called Bg), the calorimeter and neutron detector were shielded with 5 cm each of polyethylene and boron contained polyethylene.

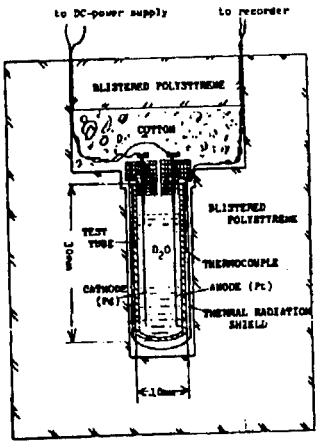


Figure 1. Cross Sectional View of Electrolytic Cell

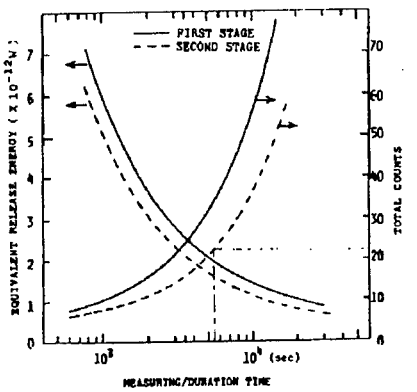


Figure 2. Measurement Time and Detection Limit

In measuring a weak line source, we cannot neglect the fluctuations in the BG counting due to changes in cosmic ray intensity. Therefore, a rem counter was installed outside the shield to monitor the fluctuations in BG by carrying out simultaneous measurements.

In parallel with the measurement of neutrons, we tried to measure the heating value within the cells, using a thermocouple mounted on the side of the electrolytic bath.

Measurement Result

Prior to the electrolysis, we performed a 30-hour BG measurement and determined the relation between the measurement time and the detection limit of nuclear fusion reaction based on the results of the BG counting (Figure 2). The measurement was carried out in 90-minute segments. When a counting value exceeding 23 counts was available, the measurement indicated a significant difference against the BG.

The electrolysis was carried out for 19 days, the BG was then measured for 3 days. Then, 2-day long electrolysis was carried out once again. Figure 3 shows the measurement results, including the first BG measurement.

We could first recognize the count that exceeded the aforesaid detection limit in the vicinity of Run No 150; the electrolysis was stopped once, then the BG measurement was started again. We could observe the increase in count even in the portions where the electrolysis was carried out again.

Figures 4 and 5 show the frequency distribution of counting values in terms of foreground and BG. A marked difference can be observed between these two frequency distributions. Some measurement data picked up during the electrolysis indicates a higher counting value that could not be observed during the BG measurement.

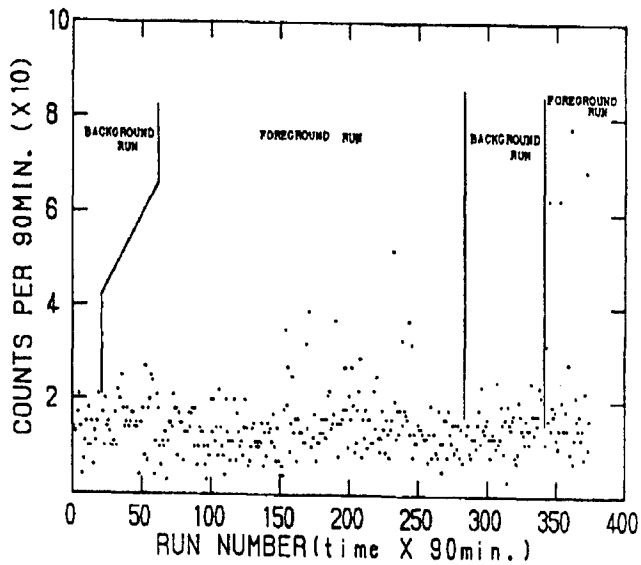


Figure 3. Aging of Neutron Detection Number

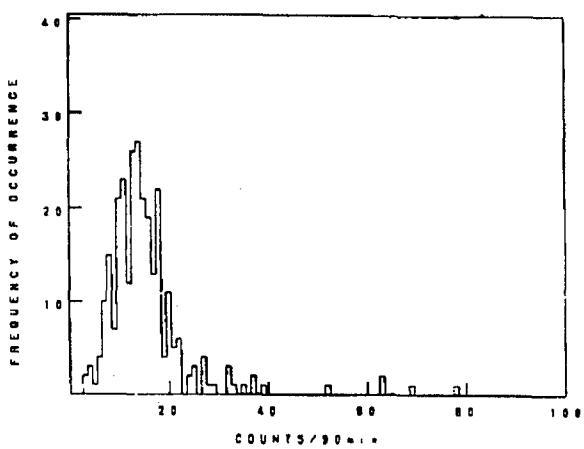


Figure 4. Frequency Distribution of Foreground Counting

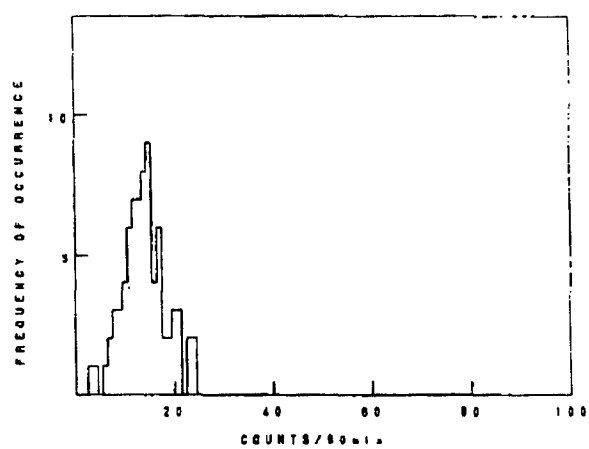


Figure 5. Frequency Distribution of Background Counting

Figure 6 shows an example of the interrelation between the counting values of the rem counter for the BF_3 and the BG monitor. We could find no interrelation between the counting values of these two detectors from the measurement results.

This signifies that the high counting values indicated in Figures 3 and 4 are produced by the BG fluctuations induced by cosmic rays.

Figure 7 shows a unique example of the measured temperature changes of an electrolytic cell. Generally, the temperature gradually drops with the time, as illustrated below (mainly caused by the decrease in the electrolyte), but the generation of heat that exceeds one joule over 5 hours was observed in the example described above. This excess heat generated is equivalent to about 200 mW. In the meantime, no increase in the detection number of neutrons was observed.

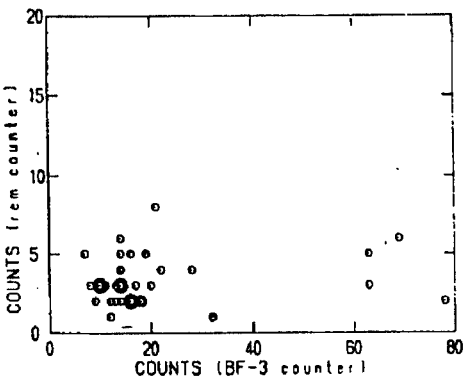


Figure 6. Counting Correlation Between BF_3 Detector and Rem Counter for BG Monitor Service
(Double or triple circles stand for overlapped observation values.)

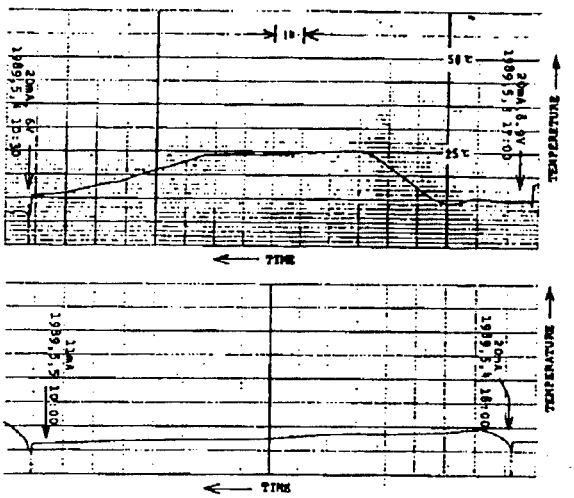


Figure 7. Example of Measurement Results of Electrolytic Cell Temperature

Conclusion

We carried out supplementary experiments of room temperature nuclear fusion based on the electrolysis method and detected neutrons estimated to be from the fusion reaction.

This experimental result reveals that the neutrons are intermittently emitted. When an attempt is made to average the neutrons thus emitted by the total time during which the electrolysis was performed, the neutron emission rate will be about 0.2 per second, thus indicating a similar value to the result of Jones.

The generation of heat exceeding 1 joule was observed during the electrolysis. In the meantime, the presence of neutrons that exceed the BG level was not detected. This signifies that the generation of heat is produced by a reaction other than fusion.

Measurement of Cold Fusion

906C0038B Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 3-4

[Article by Yukio Oyama, Tomoo Nakamura, Noboru Oyama, and Takeo Osaki, Japan Atomic Energy Research Institute; and Osamu Hatozaki, Tokyo Agricultural Engineering University]

[Text] **Introduction**

Since April this year, both the nuclear fusion reactor physics research office of Japan Atomic Energy Research Institute (JAERI) and the Koyama research office of Tokyo Agricultural Engineering University have been conducting joint research to confirm the experiment on electrolytic nuclear fusion. From the beginning, our group has continued the measurement, using an NE 213 liquid scintillator to measure DD reaction neutrons from the electrolytic cells. However, we have failed to observe the generation of neutrons that exceed the lower limit of measurement of this measurement system. It must be admitted that the conventional method, which aims at improving the analytical accuracy based on the collection of data over a long time, is subject to limitations on the improvement in measurement accuracy due to the stabilization of its measurement system and the increase in measurement time. To solve this disadvantage, we adopted a method to analyze counting data at short intervals and examine the counting distribution, because S/N-increased measurement is possible in terms of burst-like neutron emission. Therefore, we have recently continued our experiment based on this method. In this symposium, we will report on our research, centering on the measurement system of neutrons, its background, and our recent measurement results.

As illustrated in Figure 1, we tried to lay out two sets of NE 213 liquid scintillation detectors (127 mm long x 50 mm thick) so that they would face each other, and covered them with paraffin and lead in order to sample data for measurement. In this layout, if an attempt is made to set a bias value of a set point station setter, say, "Compton edge" due to the radiation source of ^{137}Cs gamma, one detector is capable of obtaining 2~4 percent efficiency, including geometrical efficiency. The counting rate under the neutron background is about 0.02 cps when a 20 cm thick paraffin layer is placed over the top of the detector. Figure 2 indicates the unfolded wave height distribution

of the spectra of the neutrons under this background. The peak of 5 MeV is a singular point that cuts the upper limit of the wave height distribution. This figure indicates a background of about 0.01 n/cm^2/s near 2.5 MeV. The shield effect of the 20 cm thick paraffin is about one-third. The lower limit of the measurement, where the fusion neutrons over the analytical fluctuations are observed, based on this system, will range from 0.05~0.1 fusions per second. In about a 30-hour long measurement time from the background counting rate and the detection efficiency described above.

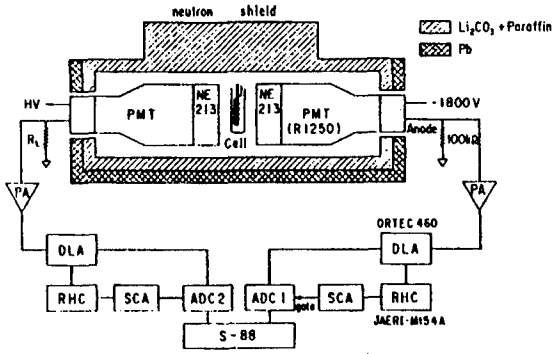


Figure 1. Layout of Detectors

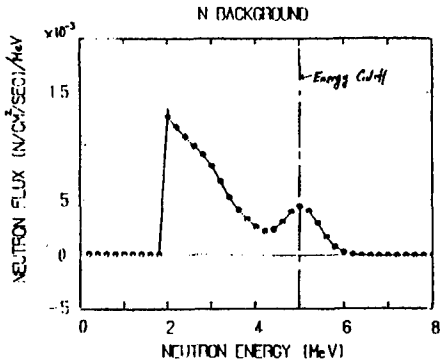


Figure 2. Spectrum of Background Neutrons

Measurement of Burst Neutrons

We measured the neutrons emitted in a burst in multichannel and scaling (MCS) mode at a minimum interval of 0.5 seconds, based on a detector's counting exceeding a preset bias, and compared the distribution of counts sampled at a specified interval with the Poisson distribution. The distribution of counts, if it is steady, is expected to conform to the Poisson distribution. The comparison was made, based on the x^2 testing method. The frequency distribution whose x^2 value is greater was compared by the foreground measurement and the background measurement. We carried out sampling measurements, using a 300 cc gas cylinder and an electrolytic cell, based on the gas pressure heat cycle method. (LANL method, but a La-Ni alloy used as the sample). We carried out measurements ranging from 1~2 hours per measurement run, and summed up a sampling number of about 1,000 per 10 several runs. When the burst time gets shorter and shorter, the better the S/N ratio can be improved by this measurement. Because the MSC method calls for a huge memory capacity, we believe that the relative time measurement method, such as LANL is most effective in such a case.

Measurement Results

We have not observed a significant difference with a long time counting method for an electrolytic cell. On the other hand, we have obtained several measurement results that exceed the test criterion according to the MSC method. However, such significant differences, although slight, can be observed in the background measurement. Provided that the measurement is carried out with a La-Ni alloy based on the gas pressure method, it can be observed that the

measurement result sharply deviates from the Poisson distribution only in a single case, as illustrated in Figure 3. Figure 4 shows the MSC vector at that time. Currently, our group is trying to conduct supplementary experiments to confirm the reproducibility of this sample.

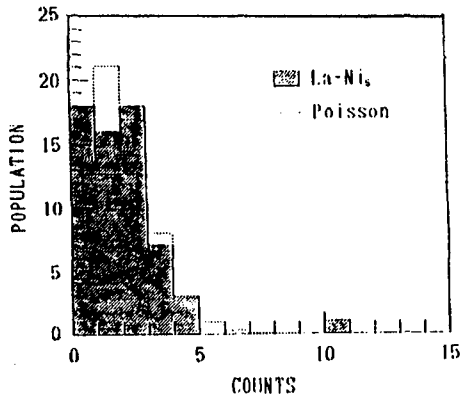


Figure 3. Comparison Between Poisson Distribution and Measured Counting Distribution

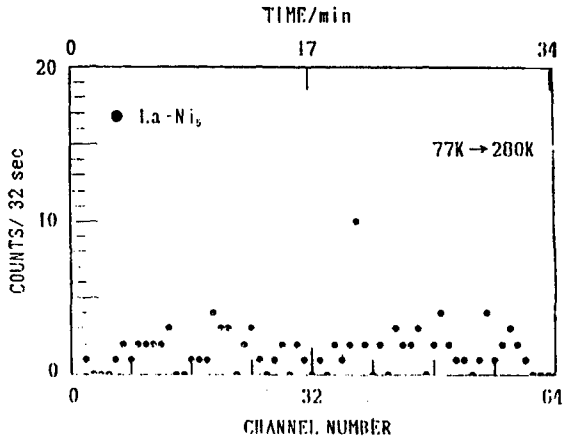


Figure 4. MCS Spectrum

Neutron Measurement Technique

906C0038C Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 5-6

[Article by Tetsuo Iguchi, Takayuki Terai, Masaharu Nakazawa, Youichi Takahashi, Tokyo University Engineering Faculty: "Report on Verification Experiment on Electronically Induced Nuclear Fusion, in Particular on Neutron Measurement Technique"]

[Text] **1. Introduction**

Ever since Fleischmann and Pons'[1] and Jones'[2] success in electrochemically induced nuclear fusion at the end of this March was reported, several groups of Tokyo University Nuclear Engineering Faculty promptly tried to conduct supplementary experiments in an effort to verify the report; they are still engaged in some subjects on the experiment. In this report, the authors will report the results of our verification experiment carried out in the first stage to confirm the contents of the experiments conducted by Fleischmann and Pons and by Jones, centering on various problems that we experienced during our attempt to detect fusion reaction neutrons, which is one of the major objectives in this supplementary experiment.

2. Brief Description of Experimental System

Figure 1 shows the outline of our experimental system, and Table 1 shows the main experimental requirements.

2.1 Electrolytic Cell

The configuration of the electrode of an electrolytic cell consists of an anode made of a ring-shaped platinum foil with a wider area and a block-shaped cathode manufactured from a molten-quenched ingot of palladium that is laid out in the center of the ring-shaped anode to obtain electric current effectively. Both the anode and the cathode are connected with a platinum wire by spot welding, and are submerged in an electrolyte where equivalent metal lithium is molten in heavy water. In addition, a stainless steel cooling water pipe is installed around the electrolytic cell to relieve vaporization of the heavy water due to joules of heat generated in the electrolyte.

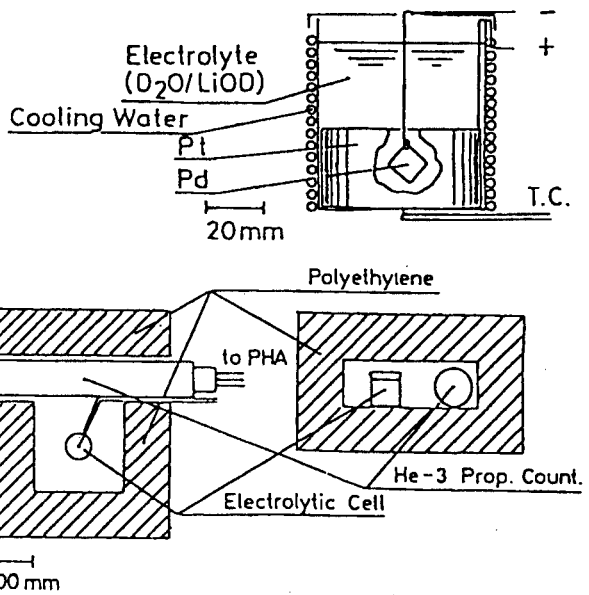


Figure 1. Outlined View of Experimental System

Table 1. Main Experimental Requirements

(Series III)	
Electrolyte:	D_2O (100 cc)/LiOD (241 mg)
Cathode:	Block (10 mm x 10 mm x 6 mm) A block is cut out from an ingot produced under molten and quenching state and annealed in air at a temperature of 850°C for 1 hour.
Voltage:	5.2~8.1 V
Current:	260~330 mA (68 mA/cm^2)
Experimental time:	550 h

2.2 Neutron Measurement System

The detection method for nuclear fusion reaction neutrons adopted for this supplementary experiment is a system based on a sample-built thermal neutron detector with a moderator that has relatively high sensitivity, is dead to γ rays, and has excellent stability for measurements over a long time. The thermal neutron detector used in our experiment is a cylinder-shaped grid ^{3}He gas ionization chamber available on the market. A mixed gas, consisting of ^{3}He 6 atm, Ar 3 atm, and CH_4 1 atm, is sealed into the ionization box. The detector is provided with a highly advanced energy resolution of 2 percent and below in a relatively larger area of 5 cmϕ x 15 cm long and a thermal neutron peak. In an attempt to detect the neutrons in our experiment, we used a ^{3}He detector and an electrolytic cell covered with a polyethylene modulator whose thickness is equivalent to 10 cm, and constantly tried to analyze the wave height of output pulses to observe the thermal neutron peak area in the extremely narrow energy

region alone, which served to raise the S/N ratio. At the same time, we monitored the stability of the detector in terms of long time measurement. The effective neutron detection efficiency in this experiment is nearly 10^{-3} in terms of a background counting rate up to 6 x 10^{-4} cps as a result when it was calibrated with a 252Cf standard neutron source.

3. Experimental Result and Judgment

Figure 2 shows a typical example of a change with time about the evaluation value of the yield of neutrons, which were continuously electrolyzed over a long time (24 days). Although it is observed that the net counting rate (BG subtracted) generally tends to shift to the positive side, the average evaluation value of the yield of neutrons is estimated to be 0.05±0.12 n/s [as published] and judged to have no significant difference. In this connection, an attempt was made to observe the experimental data every or every other day. In the meantime, it was found that the lowest value of the field of neutrons—which this detector system can detect with a significant difference of 3 σ and more in terms of the BG level—is up to about 0.3 n/s. About 14~15 days after the experiment started, we could observe the change in counting rate, which was twice the BTG level (0.72±0.10 ns in terms of the yield of neutrons). In this experiment we could observe an unexpected noise leak into the thermal neutron peak monitor region and a peak drift over several channels, as indicated in Figure 3. From the viewpoint of long time stability or electric noise, we find it necessary to discretely study the authenticity of the result or reproducibility.

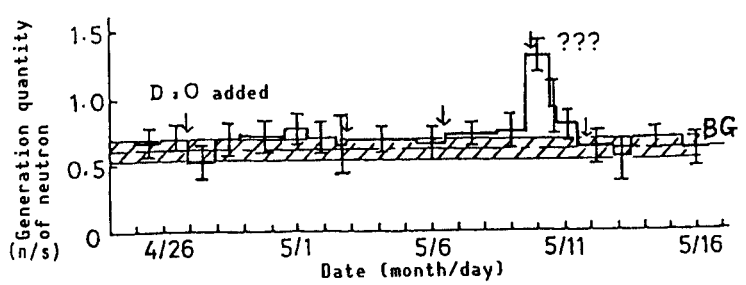


Figure 2. Example of Change With Time for the Number of Neutrons Generated

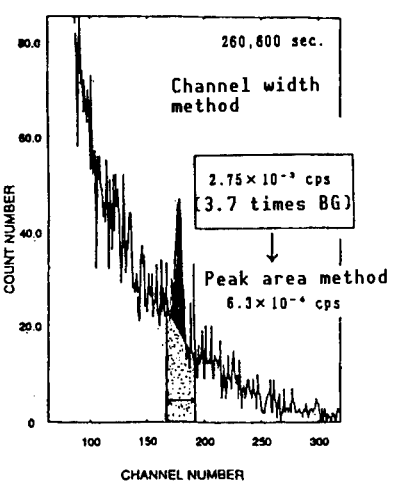


Figure 3. Example of Output Pulse Wave Height Distribution in the Vicinity of the Peak of Thermal Neutrons in the ^{3}He Gas Ion Chamber

4. Conclusion

In this supplementary experiment, we failed to obtain convincing evidence of the electrolytic fusion reaction reported by Fleischmann and Pons and by Jones. However, the neutron measurement system currently organized is not necessarily the best. Therefore, we find it most desirable to carry out a supplementary experiment once again after we try to improve the S/N ratio, such as by enhancing sensitivity of the neutron detector system, further reduction in BG, and scale-up of the radioactive source. In particular, the evaluation of "Background Run" including the habitual practice of the detector system (systematic indeterminacy) and the study of the evaluation method are considered to be more important than "Foreground Run."

References

1. Fleischmann, M., et al., J. OF ELECTROANAL. CHEM., Vol 261, 1989, p 301.

2. Jones, S.E., et al., NATURE, 27 April 1989, p 737.

Detection of Nuclear Reaction

906C0038D Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 p 7

[Article by Ryoichi Taniguchi, Takao Yamamoto, and Setsuko Irie: "Detection of Nuclear Reaction Induced by the Electrolysis of D_2O"]

[Text] **(High sensibility detection method of fusion reaction)** Nuclear signals transmitted from room temperature fusion reactions measured by Jones and others are extremely weak and near the limit of measurement.[2] This is one reason why it is difficult to carry out supplementary experiments in every country. To solve this problem, our group has studied a high sensitivity measurement method that replaced the conventional neutron measurement.

The fusion reaction induced by heavy hydrogen comprises two reactions that compete with each other, as given in the following equations:

$$d + d \rightarrow n + {}^3He + 3.27 \text{ MeV} \quad (1)$$

$$\rightarrow p + T + 4.03 \text{ MeV} \quad (2)$$

The measurement of 2.5 MeV neutrons given in reaction (1) poses serious problems, such as relatively low detection efficiency (several percent and below) and bad S/N (extremely sensitive to environmental radiation). To eliminate these problems, we tried to detect 3 MeV neutrons given in equation (2). In this case, the cathode's thickness is restricted due to the range of protons. More specifically, it must be several + μm thick and foil-shaped as well. However, the following two advantages are available from this method:

(1) The detection efficiency is excellent, more than 10 times the neutron detection (several + percent).

(2) The S/N is also about 100 times the neutron detection. (The background counting is 1 count/hour.) We can expect to detect a weak reaction, which cannot be confirmed based on the standard neutron measurement method. Figure 1 shows the experimental system we designed. The electrode is foil-shaped and is exposed to heavy water on one side and the open air on the other side. We tried to detect particles, starting with the open air side, by placing a semiconductor particle detector in substantially close contact with the foil.

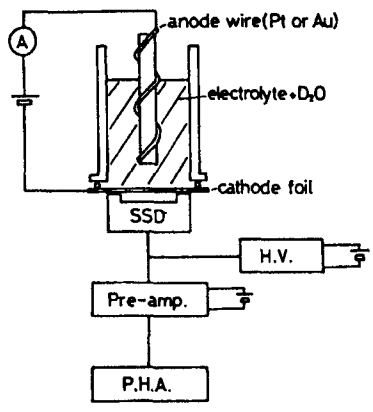


Figure 1. Measurement System

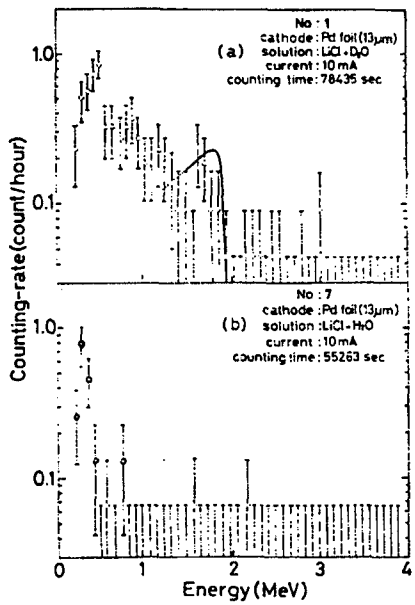


Figure 2. Measurement Example of Particle Response

(Experimental result) We have made 31 experiments up to the present. In six cases, the emission of particles could be observed. They were all induced by heavy water. Figure 2(a) shows a spectral example of emitted particles. Figure 2(b) shows the result measured with light water, based on the same experimental system, in an effort to make a comparison between the two systems. A Pd foil, which is about 12.5 μm, is used in this experiment. When the d-d reaction is assumed to occur on the surface of the Pd foil exposed to heavy water, it is observed that although the energy of generated particles is monochrome in nature, the observed particles become energy dependent for the flight distance of particles in each foil, conforming to their emission direction. The solid lines in Figure 2(a) stand for the energy spectrum predicted by calculation, assuming that the fusion reaction occurred in the central part of the Pd foil exposed to the liquid. As for the peak energy, it is in relative conformity with the experimental results.

References

1. Jones, S.E., et al., NATURE, Vol 338, 1989, p 737.

Structural Change of Pd Cathode

906C0038E Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 9-10

[Article by Ryozo Takagi and Kazutaka Kawamura, Tokyo Engineering University, Reactor Faculty; Hiroo Numata and Izumi Ohno, Tokyo Engineering University, Engineering Faculty; and Shiro Haruyama, Tokyo Advanced College: "Structural Change of Pd Cathode by Electrolysis"]

[Text] **1. Introduction**

We have received several experimental reports on neutrons being generated by occluding heavy oxygen to palladium or titanium by electrolysis or pressurization. In either case, however, the space at which the reported reaction occurred cannot be identified experimentally. When a nuclear room temperature fusion reaction occurred locally in a large bulk, we considered it very difficult to locate the specific spot at which the reaction took place. However, where a thin film is used, the change may be produced on the surface. Therefore, we find it easy to locate the spot at which the nuclear fusion takes place. In this research, we conducted electrolysis with 0.1 mole of LiOD (heavy water), using a thin film of palladium, with gold as its counter electrode, and examined, by X-ray diffraction and an optical microscope the structural change on the surface after the electrolysis. The following is the report on our research.

2. Experiment

Figure 1 shows an electrolytic cell. In Figure 1(a), a palladium electrode to which a gold lead is spot-welded is placed on the bottom of an acrylic container. In Figure 1(b), a gold counter electrode mounted with the acrylic frame is placed on the palladium electrode, and fixed with it. In this experiment, we used palladium with a surface area of about 12 cm^2 and a thickness of 0.3 mm, which is available on the market and annealed under vacuum, to carry out constant-current electrolysis. A saturated calomel electrode is used for a reference electrode. This electrolytic cell is placed in the center of a goniometer of an X-ray diffraction device and is designed to discharge electrolyte at specified times so that X-ray diffraction of the palladium electrode may be carried out. In the beginning, we tried to carry out the

electrolysis with a current density of 10 $\mu A/cm^2$ for about 4 days, but we failed to observe any change in the X-ray diffraction patterns. Then, when we tried to continue the electrolysis with 100 $\mu A/cm^2$, we could observe a slight change. However, the variation is so small that we carried out the electrolysis for about 1 week with a current density of 1 mA/cm^2. A scintillator was installed in a position 80 cm from the electrolytic cell due to its relation with the X-ray diffraction device. A copper constant thermocouple was used as a thermal monitor.

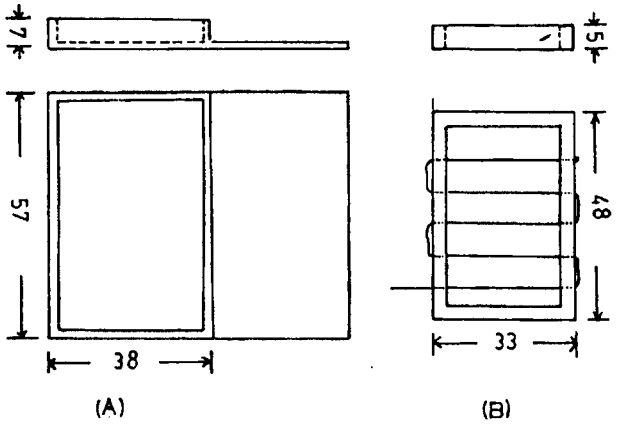


Figure 1. Electrolytic Cell

3. Conclusion

Figure 2 shows the changes in the X-ray diffraction patterns before and after the electrolysis. The digits given in the figure stand for the surface exponents that are equivalent to their peaks. The figure clearly indicates that the peak of the crystal Pd is dramatically reduced, while a new peak based on a new phase appears around the old peak. The grid constant, which is calculated from the peak position from the surface exponent 200, is turned into 3.99 Å, which is considered to be a result induced by the β phase. Figure 3 is part of the picture depicted by an optical microscope on the back side, as observed from the palladium counter electrode after the electrolysis. A molten flat surface was observed near the burst. These changes could not be observed on the sides that face the counter electrode. Since an alkali electrolysis is conducted in this experiment, they cannot be attributed to the dissolution of the electrode by electrolysis. In addition, the palladium foil is bent so that it may expand to the counter electrode as a result of the electrolysis. Therefore, it is considered that the back side of the palladium electrode is subjected to compression stress. We could not find any significant difference between the γ rays and the background to be monitored in the experiment. Moreover, we could find nothing that suggests the generation of excess heat as for thermal problems. We could not observe the organization illustrated in Figure 3 [not reproduced], but only locally on the back side of the palladium electrode. Even if it is assumed to be a result of a nuclear fusion reaction, its change is extremely weak together with the heat of rays. Therefore, it is very difficult to detect the reaction based on the current method. To solve this problem, we are scheduled to continue this experiment based on a further enhanced method.

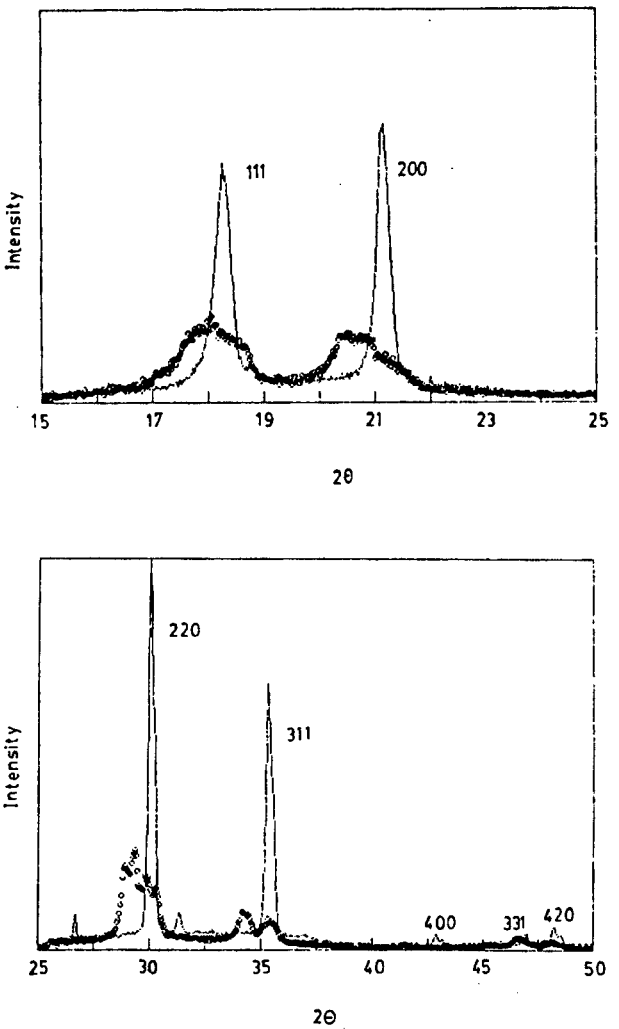


Figure 2. X-Ray Diffraction Patterns of Palladium Before and After Electrolysis

_____ Pattern before electrolysis.

ooooo Pattern after electrolysis.

Electrolytic Nuclear Fusion--Calorimetric Experiments

906C0038F Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 11-12

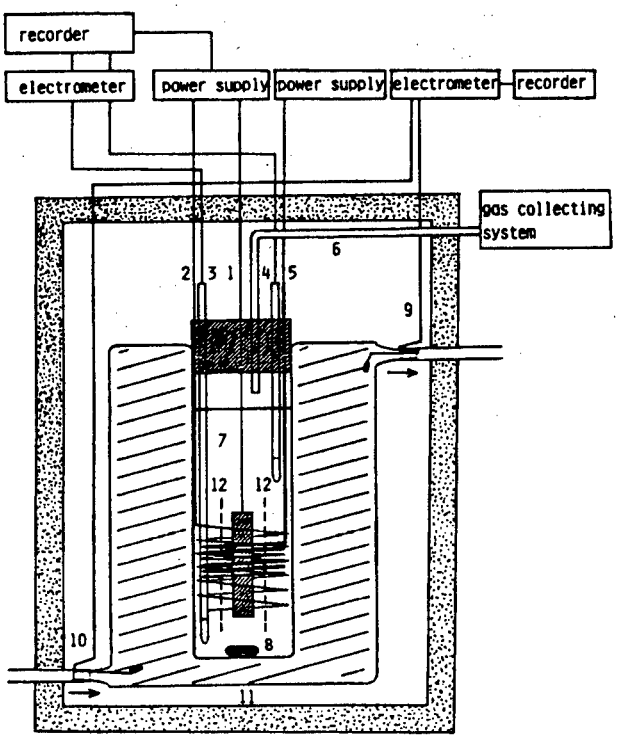
[Article by Noboru Oyama, Takeo Osaka, et al., Tokyo Agricultural Engineering University, Engineering Faculty; Mineo Imamura, Yoshitomo Uwamino, et al., Tokyo University Nuclear Research Institute; Yukio Nakamura, et al., Japan Atomic Energy Research Institute, Tokai Research Institute; and Takaharu Gamo, Matsushita Electric Industrial Co., Ltd., Research Institute]

[Text] **Purpose**: Ever since the reports on room temperature nuclear fusion based on the electrolytic method by Fleischmann and by Jones, we have been conducting supplementary tests about their experiment and associated developed experiments. By changing the types of electrodes, their shapes and volumes, electrolyte, and electrolytic modes, we have tried to electrolyze the substances in order to measure neutrons, heat, and tritium, and analyze and determine generated vapor. In addition, we have built various kinds of experimental systems based on the high pressure bomb method. In this article, we will report the results of thermal measurement in terms of the electrolysis of heavy water based on the application of palladium cathode.

Experiment: In our experiment, we adopted 20~100 mℓ of 0.1 M $LiOD/D_2O$ and 0.1 M $LiOH/H_2O$ as an electrolyte, and used a palladium (purity 99.9 percent and more) rod (1~10 mmϕ x 5~100 mm) long) and a sphere (15 mmϕ) as a cathode. As an anode, we adopted a platinum wire. The electrolysis was carried out based on the two electrode type constant-current electrolysis method. The current density was about 20~500 mA cm^{-2} and the electrolysis time lasted for 3~10 days. The thermal measurement was carried out based on the application of a water jacket-equipped electrolytic cell by circulating constant temperature water (Figure 1). This measurement method is a constant temperature wall-type calorimetry.

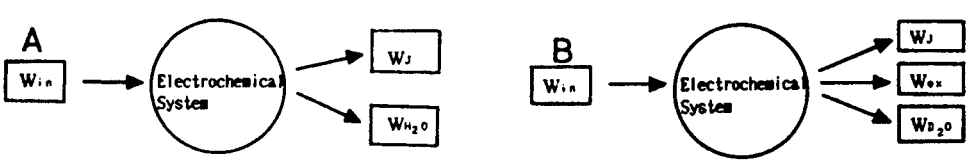
Result: Figure 2 is a schematic view that depicts the energy balance in the electric distribution of light water and heavy water where "superheat (Wex)" is expected to be generated. Where W_{in} stands for inlet power, W_J for joule heat, and W_{H_2O} (or W_{D_2O}) stands for the energy required for the decomposition of light water (or heavy water). Assuming that the current, voltage, and decomposition voltage of heavy water are expressed by I, E_{app}, and 1.53 V

($= -\Delta H_{D_2O}/2F$), the following values can be obtained: $W_{in} = E_{app} \times I$, $W_{D_2O} = 1.53 \times I$, $W_J = (E_{app} - 1.53) \times I$. They can also be expressed as $W_{ex} = W_{out} - W_J$ (W_{out}: output heat). When some superheat exists, it can be expressed by $W_{ex} > 0$. For example, it is expected that the thermal efficiency (ϵ) expressed by W_{ex}/W_{in} may assume a positive value.



1: Cathode
2: Anode
3,4,9,10: Thermistor
5: Heater
6: Gas outlet
7: Electrolyte solution
8: Stirrer bar
11: Electrolysis cell with water jacket
12: Membrane separator

Figure 1. Electrolytic Cell for Calorimetric Measurements



$W_{out} = W_J = W_{in} - W_{H_2O}$
$W_{in} = E_{app} \cdot I$
$W_{H_2O} = -(\Delta H^{\circ}_{H_2O}/2F) \cdot I$
$\epsilon = W_{ex}/W_{in} = 0$

$W_{out} = W_J + W_{ex} = W_{in} - W_{D_2O} + W_{ex}$
$W_{D_2O} = -(\Delta H^{\circ}_{D_2O}/2F) \cdot I$
$W_{ex} = W_{out} - W_J$
$\epsilon = W_{ex}/W_{in} > 0$

Figure 2. Energy Balance in Electrolysis of (A) H_2O and (B) D_2O

As a result of a series of measurements that we have made in the past, we have observed such data, which is partially considered as superheat due to the difference in the preconditions of the palladium electrodes. To be more

specific, when an attempt is made to heat a palladium rod (3 mmϕ x 46 mm long) to near the melting point temperature, then quench the rod in heavy water, further anneal the rod under decompression state so as to turn the rod into a cathode, and electrolyze the heavy water with this cathode, the following values can be obtained: W_{in} = 1.26 W, W_{out} = 1.19 W, W_{D_2O} = −0.43 W, W_J = 0.83 W, and W_{ex} = 0.36 W. As a result, the thermal efficiency was evaluated as ϵ = 28.4 percent. The "fine cracks" formed during the process, ranging from heating, quenching, and anneal processing, are considered to be associated with the generation of superheat. However, when no attempt is made to carry out the pretreatment of electrodes in this manner, we failed to observe "superheat." We do not believe that our measurement cell is the main cause of the superheat.

In this manner, we have obtained some experimental results that we find similar to "superheat" in our experiment. However, we must admit that our measurement system (semiclosed system) is not always perfect in its accuracy. Therefore, we are currently trying to develop a more perfect closed type thermal measurement system and a twin type thermal measurement system in order to carry out more accurate thermal measurements.

Chemical Heat Production

906C0038G Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 13-14

[Article by Motoji Ikeda and Hiroyuki Miyamaru, Department of Physics, Osaka University: "In Situ Observation of Pd Electrode and Several Trials in Cold Fusion Research Chemical Heat Production"]

[Text] Every attempt is being made in the pursuit for cold fusion from the standpoint of radiation measurement, such as the detection of tritium or attached γ-rays. The research that challenges the "limit accuracy" called for to detect weak neutrons is a demonstration experiment, carried out to confirm whether or not cold fusion occurred on the level reported by Fleischmann and by Jones. The most important thing to do is to pursue the cause of heat production described in Fleischmann and Pons' report, and clarify whether or not it is induced by nuclear fusion or identify the nature of the chemical reaction.[1] We believe it is most desirable that only a handful of researchers should challenge the "limit of accuracy" under the experimental conditions that are thought to promote room temperature nuclear fusion reactions without spending much time and cost. Even when "cold temperature nuclear fusion" ends up as an imaginary nuclear fusion, it is desirable that the research investment including time will serve to produce a secondary achievement that can be applicable to other fields.

During our attempt to measure neutrons in a BF_3 rem counter, we observed something wrong with "the neutron counts" that followed with a time lag in the current of the electrolysis due to a rise in the temperature of heavy water or the generation of water vapor. Allowing experts to be engaged in the measurement of weak neutrons, we are trying to continue our research in an effort to define the physical properties of the materials.

(1) In-Situ Observation of Electrodes During Electrolysis

If nuclear fusion can produce local melting, it is considered that the Pd melted from the microscopic region of the electrodes will be ejected and solidified. This is something like pillow-shaped lava generated by the ejection of lava from the sea bottom in earth science. Jones also reports that metals (electrodeposits) adhered to the surface, just like plating, since a lot of metal ions were contained in the electrolyte that they used in their

experiment. If we can carry out "in-situ observation" of the surface of the electrodes with a microscope, we can trace the plated state or the hydrogen brittleness of the Pd electrodes, or the generation of blistering cracks. Since we are trying to demonstrate cold fusion from a different standpoint with regard to the measurement of neutrons, we conducted in-situ observation of the surface of the Pd electrodes.

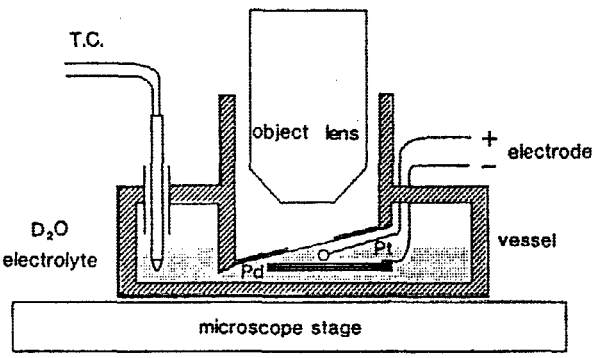


Figure 1. Pd Electrode Microscope and In-Situ Observation Device
This device can be applied to develop bacteria present in electric plating or solvent.

Figure 1 shows the outline of an "in-situ observation" device designed to observe the electrodes with an optical microscope. By placing the tube of the microscope near the electrodes, their images can be picture-recorded with a videotape recorder in continuous mode at a magnification of up to 300. Figure 2 [not reproduced] is a photograph that depicts the deuterium foam generated from the Pd surface observed with this microscope. We are trying to look for the process of the electrodeposits (plating) of the metal with this device. In addition, we are looking for metallurgical information, such as Pd splintering, by observing the electrodeposits with EPMA and the possibility of Pd melting as well.

(2) Laser Light Irradiation and High Pressure Compression Under Electrolytic Hydrogen Occlusion

In cooperation with Sawamoto and Yoneda (Earth Science Department of Nagoya University), we are trying to conduct a deuterium occlusion experiment based on "electrolysis under high pressure," using a cubic anvil. As the span between deuterium is contracted by about 1 percent ($\Delta V/V$ = 3 percent) by the application of 60 kbar, if it is assumed that the span between grid positions are also contracted by 1 percent, then the nuclear fusion reaction cross sectional area is expected to increase e times or 10 times. The orthodox method to compress without implosion, as in the case with laser fusion, may be defined as a high pressure compression experiment. The electrolysis under high pressure features a new experimental performance.

If it is possible to excite deuterium contained in the Pd electrodes with radial ray irradiation or laser light irradiation, or provide some kinematic energy (NEAT) to the deuterium by exciting electrons, it is assumed that the nuclear fusion reaction areas would be sharply increased. To our great regret,

however, the exothermic reaction did not increase as was supposed, although it was observed that the hydrogen occlusion effect was slightly affected according to the experimental results.

(3) Bending Exothermic Experiment of Pd Electrodes (Yuri, Gera experiment)[1]

The surface of the Pd electrodes, to which deuterium was sufficiently occluded, was cleaned with acetone; then the electrodes were supported at two points, and bent in the central part held with a thermoelectric rod. The temperature of the electrodes rises dramatically and their reaction finishes in a few minutes, as illustrated in Figure 3. The heat generation indicated a higher value compared with the 10 W/cm^3 reported by Fleischmann and Jones. The continuation time was 1 or 2 minutes. No neutron was detected. We also tried to carry out an experiment on Pd electrons with hydrogen occluded. As a result, we observed the generation of heat even among hydrogen-occluded Pd electrodes, as shown in Figure 3, which revealed that it was "chemical heat generation."

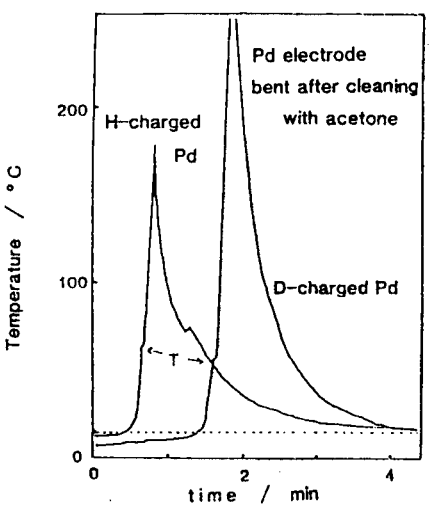


Figure 3. Chemical Heat Production Induced by Pd Electrode Bending Experiment After Acetone Cleaning
Heat production of 10 W/cm^3 and higher is observed. It is found that the heat is produced by hydrogen additive reaction of attached acetone.

When an attempt is made to wipe out the surfaces of electrodes with alcohol without cleaning the surfaces with acetone, it is found that no heat will be generated. The surfaces are subject to crack generation due to hydrogen brittleness of Pd, and acetone (about 1~2 mg) adheres to the surfaces. If the Pd is subjected to mechanical bending, the hydrogen will be rapidly ejected so that heat may be generated by the hydrogen addition reaction of $(CH_3)_2CO + H_2 \rightarrow (CH_3)_2CHOH$, thereby producing alcohol. Even when an attempt is made to intermix acetone into the electrolyte, this reaction definitely occurs. This experiment is not directly associated with "room temperature nuclear fusion." However, when an attempt is made to bend the Pd electrodes, the hydrogen between the grids will move, thereby producing a drastic hydrogenation reaction to such an extent that the plastic for the support base will be

molten, which is interesting for us to observe. If 1 percent hydrogen carbon is contained in the Pd electrodes as an impurity substance, it can be calculated that the heat production of the Pd electrodes will be equivalent to 10 kJ/cm^3 by the generation of CH_4 or organic substances. This value is still small when compared with the 4 MJ/cm^3 insisted on by Fleischmann and Pons (it continued more than 100 hours), but we find it necessary to reconsider the propriety of the evaluated value 4 MJ/cm^3. If we assume it is a result of chemical reaction of impurities, the heat production will remain up to several kJ/cm^3.

(4) Spallation Nuclear Fusion of LiD Under Hypothesis

Observation of the electrodes reveals the deposition of white-colored inorganic substances. It is assumed that the deposited Li turned into LiD, which produced the reaction of $2LiD + D_2O - Li_2O + D_2$. If this hypothesis is correct, the generation of traces of neutrons is attributed to D - D nuclear fusion induced by D^+, which was accelerated to several 10 keV due to the charge produced by the spallation of LiD crystalline. The heat is produced by the chemical reaction induced by the hydrogenation of impurities or Pd or Li.

Appreciation: We express our sincere gratitude to Kikuo Shimizu who helped us conduct the tritium detection experiment, Ryoto Takahashi who helped us conduct the measurement of neutrons, and Koh Sawamoto, Akira Yoneda, and Tadayuki Itoh who helped us conduct the high pressure compression experiment. We are also thankful to the precious advice given by Muneyuki Date and Kunio Ozawa.

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Confirmation Experiment of Fusion Reaction

906C0038H Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 15-16

[Article by Enzo Tachikawa, et al., Chemical Department of Japan Atomic Energy Research Institute (JAERI); Yoshimaro Yamanouchi, et al., Physical Department of JAERI; and Masakazu Tanase, et al., Isotope Department of JAERI, and Akimichi Hishinuma, Combustion Material Engineering Department: "In Search of Cold D-D Nuclear Fusion"]

[Text] Our group has conducted the following experiment to confirm the cold nuclear fusion reaction based on the heavy water electrolysis method and the deuterium gas pressure method. (Reference documents: "Room Temperature Nuclear Fusion Confirmation Experiment" (First Report) JAERI M 89-142, 1989.)

(1) We tried to measure the generation rate of neutrons, neutron energy, the generation of γ, the production of ^3H, and the exothermic quantity based on the heavy water electrolysis method where Pd, Ti, and the like are used as a cathode.

(2) We tried to measure the generation rate of neutrons based on the cooling to heating method where deuterium was introduced into Ti particles under pressure.

(3) We tried to analyze their structure based on X-ray diffraction of Pd and neutrons where electrolyzed deuterium is introduced.

We have conducted the electrolysis method experiment more than 25 times and the pressure method experiment in more than 40 cycles, but failed to obtain the results to confirm the expected reaction. In this report, we will introduce the outline of our experiment and discuss what must be done in the future.

Experimental Method

Heavy water electrolytic method: The requirements for electrodes, electrolyte, and electrolysis are as follows: Electrodes: various Pd metal (purity > 99.5 percent, sheet/round bar/square bar), powdered Pd sintered body, Ti metals

(impurity > 99 percent, sheet/round bar), Pd-Cu alloy (55 at% Pd-45 at% Cu, β), and the like are pretreated according to the following four methods (1)-(4):

Pretreatment method: (1) vacuum deaeration at a temperature of 600 or 900°C; (2) introduction of deuterium into a metal from the gaseous phase after vacuum deaeration, (3) metal electrolyzed at a positive potential maintained for a fixed time in a heavy water solution.

Electrolyte: (1) 0.1~0.2 M $LiOH/D_2O$, (2) 0.1~1.5 M $LiOD/D_2O$, (3) 0.2~0.5 M $LiCl/D_2O$, (4) 0.5 M LiCl + various kinds of metal ions/D_2O, pH1~2.

Electrolytic method: Electrolyzed based on a constant current method or a pulse overlay current method, using a two-electrode type electrolytic cell. A Pt cable used as an anode, where its diameter ranged from 0.5~1 mm. The current, the voltage, and the electrolysis time where specified as follows: Current density: 4~600 mA/cm^2; voltage: 5~50 V; electrolysis time: 3~670 hours.

Ti/D_2 method: The material of Ti, the preparation of a sample, and the experimental method are:

Sample preparation: Sampled about 80 g of Ti particles (purity > 99.5, 2~12 mmϕ) in a SUS made reaction vessel, activated these particles at a temperature of 600°C under the vacuum (10^{-6} torr), then prepared the samples Ti/D_2 based on the above methods (from (1) to (4)). (1) Cooled the vessel at the temperature of liquefied nitrogen and introduced D_2 gas (purity > 99.8 percent).
(2) Exhausted the gas after the completion of step (1), then introduced D_2 gas while the vessel was kept at a temperature of 450°C. Cooled the vessel down to the temperature of liquefied nitrogen, introduced D_2 gas, then exhausted excess gas. (3) Repeated a cycle of heating and cooling of the sample between the room temperature and 520 K thrice after the completion of the step (2), then exhausted the gas at the temperature of the liquefied nitrogen thus maintained. (4) Kept the sample thus prepared by step (3) at room temperature, introduced D_2 gas, then gas again.

Cooling-heating operation: Allowed the liquefied nitrogen for vessel cooling to get vaporized naturally, then increased the temperature of the sample up to room temperature. Then, filled the vessel with liquefied nitrogen again, made sure that the sample was cooled to a satisfactory extent, then heated in a similar manner. Repeated this cooling and heating operation cycle about 10 times, using the same sample.

Measurement of neutrons: Measured the neutrons generated by the d-d fusion reaction based on (1) total neutrons counting method, and (2) neutron spectrum method.

Total neutrons counting method: Used a detector consisting of a cylinder-shaped paraffin moderator (300 ϕ x 410 mm long) and 12 BF_3 proportional counters, shielded the entire body of the detector with a water tank, which

included a cadmium plate (0.5 mm thick), paraffin (50 mm thick), and boron, and reduced the background (BG). The BG discrete value was (3.2±0.1) x 10^{-2}/s. Recorded the discrete values counted by two sets of counters (one set comprises six counters) on a printer at a fixed interval of 1~60 minutes to measure the neutrons. The counting electric field of this device was 5.0±0.2 percent. Measured the multichannel time spectrum with a total time range and checked for simultaneous counts to confirm the simultaneous generation of neutrons (burst). When 3σ of the BG discrete value is defined as the lower limit of the detection, the detection limit of the neutron generation rate was 0.1 times per second (3 hour measurement).

Neutron spectrum method: Used two detectors consisting of an NE-213 type liquid scintillator, and a photomultiplier RCA8854. About 96 percent of the total cubic angle of the detector was shielded with 5 cm thick lead blocks to reduce the background of γ rays. Amplified the signals transmitted from the detectors, then picked up those signals that exceeded a specified discrete level, and displayed them as a pulse height spectrum. The effective detection efficiency of the spectrometer used in this experiment was 2.2 percent and the BG discrete value was about 2 x 10^{-2}s.

γ-ray measurement: Measured the γ rays generated when the neutrons or protons generated by the fusion reaction were caught by the deuterium in the electrolyte, using a 20 cm ϕ x 25 cm NaI detector.

Measurement of ^{3}H and Exothermic Quantities

Measured the density of ^{3}H contained in the solution after the electrolysis based on the liquid scintillation method. Measured continuously the temperature of the solution by a thermocouple installed near the cathode in the electrolytic cell to check for the presence of superheat production.

Structural analysis of electrodes: Examined the structure of the electrodes after the completion of the electrolysis experiment based on the X-ray and neutron diffraction methods.

Diffraction device: Used an X-ray diffraction device powder testing, which comprises an SG-7 type goniometer and an NaI (Tl) detector, and a neutron diffraction device, which comprises a three-axis type neutron spectroscope and a ^{3}He gas seal type detector and the like (JRR-2).

Results

Neutrons: We concluded that the generation rate of neutrons is 0.1 times and below per second in the heavy water electrolytic method, and the deuterium gas pressure method resulting from the total neutron counting method and the neutron spectrum method.

γ-rays: Failed to observe the peak of the γ rays of 6.26 MeV (by neutrons) and 5.49 MeV (by protons).

^3H: The ^3H density in the electrolyte was identical to the BG density in the heavy water within a range of determination error. We held the Pd electrodes at a positive potential in heavy water, then measured the ^3H contained in the heavy water, but could not detect the ^3H which exceeded the BG.

Exothermic quantity: We failed to observe superheat generation in every electrolysis experiment.

Structural analysis: After electrolysis, the Pd increased by even 10 percent in the outside dimension. Moreover, a marked change occurred, so that cracks generated on the surface may be observed by naked eyes. The generation of the α phase and β which forms the face-centered cubic of the Pd electrode space group Fm3m could be confirmed in the Pd. The result of neutron diffraction revealed that a maximum of 78 percent of heavy hydrogen was contained in the β phase.

Progress of Cold Fusion Experiment

906C0038I Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 p 17

[Article by Michio Yamawaki, Atomic Energy Research, Tokyo Industrial University]

[Text] **1. Introduction**

Cold fusion, if it is true, must be a very interesting research subject for us researchers, since its concept is quite different from the conventional nuclear fusion induced by high temperature plasma. The author tried to conduct a preparatory experiment from the standpoint of the mutual actions conducted between hydrogen and materials and report the progress of the experiment: During the experiment, the author paid specific attention to the following points:

(1) What kind of material produces the most effective cold fusion reaction if it is used as an electrode?

(2) In what state does a hydrogen isotope exist in the material (when the cold fusion reaction occurs)?

2. Experimental Method

The following two types of electrode materials were adopted for a cathode in the experiment:

(1) Palladium plate (made by Nihon Electric Bulb Industry Co., Ltd., 5.0 cm x 2.5 cm x 0.5 mm t)

(2) Uranium titanium block (UTi_4, weight 2.0 g)

In either case we used platinum anodes (made by Nihon Electric Bulb, 4.0 cm x 2.0 cm x 0.5 mm thick). For the electrolyte, we used a solution produced by melting in about 0.01 mol of Li block in 0.01 liter of heavy water.

We tried to shield all the surfaces of a beaker that contained the electrolyte with a 10~15 cm thick polyethylene block in order to detect the generation of neutrons—which is most important to confirm the cold fusion reaction—using a ^{3}He counter installed inside the beaker.

3. Progress of Experiment

We have failed to confirm the cold fusion reaction in the case when either a palladium or a uranium intermetallic compound was used. As a matter of fact, the background was subjected to a marked change, which ranged from 1.0~80 cpm, with the progress of time due to an unstable action of a detector. This clearly indicates how difficult it is to measure the dose of weak neutrons.

Since the cold fusion reaction was reportedly confirmed in the early stage in terms of palladium, we carefully studied the dependence on the current density of electrolytic time, comparisons between light water and heavy water, and the like. However, we could not find any significant difference between the dose of the neutrons detected and the background.

On the other hand, since the author already clarified that uranium titanium alloy can absorb a large quantity of water at room temperature, the alloy was expected to absorb hydrogen effectively even in the case of electric decomposition. However, when an attempt was actually made to conduct electric decomposition (current density 10 mA/cm^2), hydrogen was generated on the surface of a chip that clamped the alloy. Moreover, the administrative areas where we are conducting our experiment are subject to a large noise produced by the air conditioning systems or other experimental facilities. As a result, even the average background reached about 10 cpm. Therefore, it must be admitted that our environment is not necessarily suitable for our experimental purpose. Even in the actual measurement, we have not obtained neutrons yet.

4. Conclusion

We have not yet obtained a significant result that is directly associated with the cold fusion reaction. This must be attributed to it being extremely difficult to detect the presence of neutrons that exist in trace quantities. Even in the future, it may be necessary to study various types of electrode materials or many kinds of processing methods that meet the experimental requirements as reported in this paper. The author finds it more imperative to establish the standard methodology in terms of the measurement of neutrons as a prerequisite.

Window of Cold Fusion

906C0038J Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 21-22

[Article by Akito Takahashi, Osaka University: "Window of Cold Fusion and Some Results of D_2O Electrolysis Experiment"]

[Text] **1. Potentiality of Room Temperature (Cold) Nuclear Fusion**

No matter what mechanisms may be adopted to bring two protons nearer, it is very important to take a satisfactorily large probability exp (-G) for them to penetrate the Coulomb barrier of the nucleus. The D-D reaction rate λ_{DD} is given by equation (1) and the Gamov factor is given by equation (2) in terms of any arbitrary potentiality U(r). The charge screening effect produced by the electronic clouds in a hydrogen occluded metal effectively reduces the deuteron charge (specific charge $\eta^{1/2}$) and increases λ_{DD}.[1] If an attempt is made to indicate η as in equation (3) based on the Bohr type shielded potentiality represented by $U(r) = U_0(r)\exp(-(r-r_0)/a_s)$; $U_0(r) = z_1z_2\ e^2/r$, and estimate the screening effect, the effective deuteron charge can be expressed as in Figures 1 and 2. Where $\epsilon_d = E_d/z_1z_2e^2$, and E_d is deuteron kinematic energy (eV) and "b" can be decided by the relation $b^{-1}\exp(-(b-r_0)/a_s) = \epsilon_d$.

$$\lambda_{DD} = 3 \times 10^{-13} \cdot E_d^{-1/2} \exp(-G) \tag{1}$$

$$G = 2\sqrt{2md/\hbar^2} \int_{r_p}^{b} (U(r)-E_d)^{1/2} dr = 1404 z_1 z_2 \eta E_d^{-1/2} \tag{2}$$

$$\eta = (z_1z_2e^2)_{eff}/(z_1z_2e^2) = 2/\pi \cdot \epsilon_d^{1/2} \int_{r_d}^{b} (r^{-1}\exp(-(r-r_0)/a_s)-\epsilon_d)^{1/2})\, dr \tag{3}$$

Since the distance that allows two deuterons to approach each other freely can be stated by r_d to $10a_s$, the distance must be r_d to about 0.1 Å to obtain $\lambda_{DD} = 10^{-30}$f/s/D, while it may be r_d to about 0.01 Å to obtain $\lambda_{DD} = 10^{-20}$ f/s/D. Or it may be understood that the main conditions for the three-body (cascade) reaction[1] 3D → d + α + 23.8 MeV may be something like $r_d \sim 10^{-11}$cm. In the stabilized position ("0"- site) or PdD, the distance is r_d~2.8 Å, which is entirely different from the aforesaid "feasible" conditions. This indicates how high and narrow the window of the room temperature nuclear fusion is.

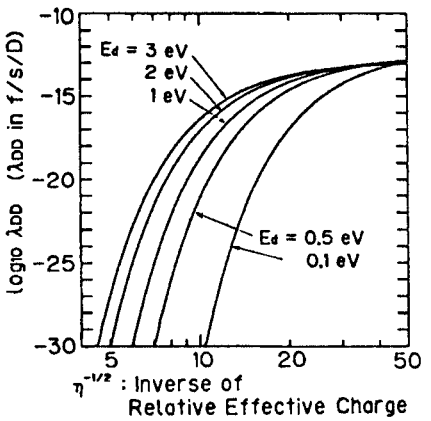

Figure 1. Fusion Rate as a Function of Effective Deuteron Charge

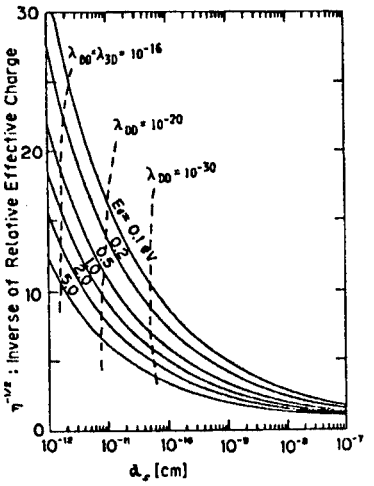

Figure 2. Effective Deuteron Charge Calculated With Bohr Type Shielded Potential

However, it seems that there exists some region where r_d is decreased sharply in a certain probability due to nonsteady state (due to the diffusion of D) in the Pd material on the way to the discharge of D.[2] After the formation of PdD as a result of sufficient charge, D contained in the Pd lattice is brought into the ground state of an harmonic oscillation ranging from $\hbar\,\omega_0$~60 MeV, and turns to an Λ type wave function; its product with the wave function of the adjoining D is extremely small. However, if it is possible to induce a high level of excitation (up to 10 $\hbar\,\omega_0$ = 0.6 eV), it is considered that it changes into a U-shaped wave function and approaches the neighboring D at the position of "t." Furthermore, the reactive deuteron flux may be increased by the maximum ω times (10^{14}).

If it is possible to extract "this energetic screening effect to a satisfactory extent," then nuclear heat generation can be expected, since it turns into $\lambda_{DD} > 10^{-12}$f/s/D.

2. Deuteron Electrolysis Type Experiment

The experimental requirements are specified in reference 3 in detail. We are trying to carry out biased-pulse electrolysis operation at 4 minute intervals in an effort to promote the fusion nonsteady process (D to D approach by charge and discharge) under the charge of D induced by the electrolysis to the Pd electrode. In an attempt to monitor the quantity of neutrons, we are trying to regularly measure five quantities; such as the time correlation between MCS (9s/ch) and biased pulse, the wave height distribution of ^{3}He (n·p) reaction, the wave height distribution of NE213 (neutron energy check), and the wave shape distribution of NE213 (discrimination of neutrons, γ rays, or noise) based on the application of a cross check system, which is designed to cross check the time patterns for their generation quantity, using two dissimilar theory-based detectors, the ^{3}He-Bonner counter and the NE213-5 inch ϕ x 2 inch. The electrolytic device used in this experiment is a separation cell type,

where a solution of D_2O (500 mℓ) + Li_2SO_4 (1 mol/ℓ) is used. Figure 3 shows a typical example of time-pattern of neutron count-rates. The fluctuations in the background of cosmic ray neutrons were corrected based on the application of the experimental results conducted by the Physical Research Institute of Tokyo on the same day. The correction was made on up to 5 percent degree. The increase in the quantities of significant neutrons was observed as a similar pattern by both the detection systems from 130 hours after the charge of D started. However, it returns to the BG level on and after 300 hours. Table 1 shows the summary result of neutron yield (n/s/cc). Reproducibility was observed in the case of No 8 and No 19 under the same experimental requirements. Central focused type Pd rod electrodes are used in the experiment.

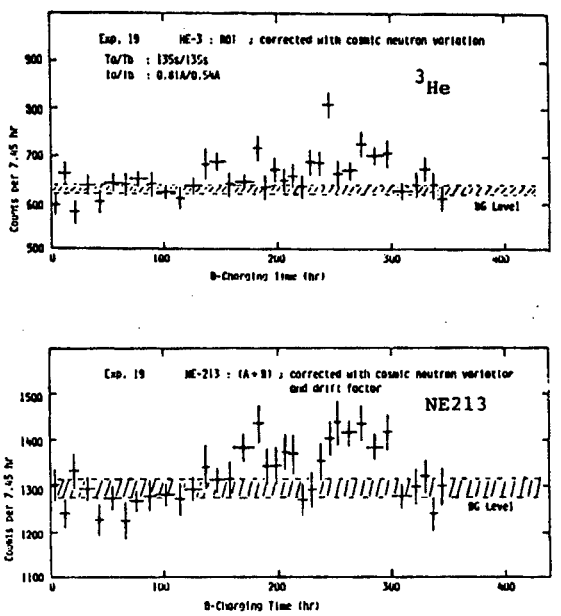

Figure 3. Typical Time-Pattern of Neutron Count Rates for D_2O Electrolysis With Biased-Pulse Operation

Table 1. Summary of Typical Results

Experiment No.	Pd purity (%)	Pd size (mm)	D-charging time interval (hr)	Neutron yield (n/s/cc)
8	99.99	10^{ϕ} x 11^{ℓ}	192 to 257 (65)	1.00 ± 0.20
13	99.95	8^{ϕ} x 10^{ℓ}	195 to 315 (120)	1.00 ± 0.25
19	99.99	10^{ϕ} x 11^{ℓ}	0 to 134 (134)	-0.20 ± 0.33
19			134 to 348 (214)	1.14 ± 0.36
19			241 to 300 (59)	2.42 ± 0.49

A dim peak can be observed near the channel, equivalent to the edge of En = 2.45 MeV in terms of the wave height distribution (the ratio with BG) in the section where the increase in neutrons is observed. The generated neutrons are considered to be due to the reaction of $D(d,n)^3He$.

The results indicated in Figure 3 seem to support the theory that the D–D reaction of 1~2 f/s/cc is produced in the region where the D/Pd ratio ranges from 0.01~0.1 in the D charge diffusion process claimed by Bussard.[2]

In the future, we intend to continue our experiment to determine whether it is possible to complement the excitation by optical radiation.

Concluding this report, the author would like to express his thanks to Toshiyuki Iida, Shigeo Yoshida, Kyuji Sugimoto, and Fujio Maekawa, Osaka University, and Tadao Yatsunobor, Mitsubishi Metal Corp.

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'Nattoh' Model for Cold Fusion

906C0038K Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 23-24

[Article by Takaaki Matsumoto, Engineering Faculty of Hokkaido University]

[Text] In this article the author will propose the "Nattoh Model," which is one of the assumptions about cold fusion.[1,2] Based on this model, the author will discuss the mechanism of cold fusion, the unique performance of the γ ray spectrum, neutron discharge in plural mode, and the distribution of nuclear fusion product materials.

Nattoh Model: Since the deuteron contained in a metal is compressed under very high pressure, it can be easily expected that more than three particles of deuteron are collected on lattice defects, thereby forming clusters. Among these clusters, the electrons move accompanied by deuterium whose mass is heavy, thereby increasing its effective mass. As a result, the distance between the deuterium contained in the clusters is short enough to produce nuclear fusion.

The following two reactions can be observed in a plasma phase:

$$D + D \rightarrow T + P \qquad (A)$$

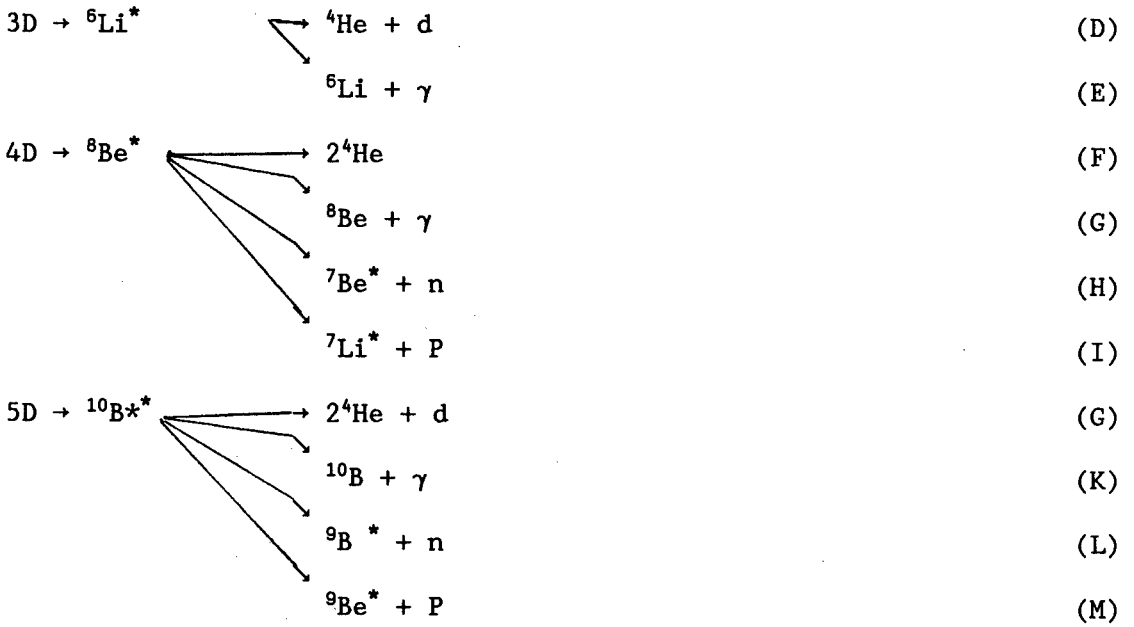
$$D + D \rightarrow {}^{3}He + n\ (2.45\ MeV) \qquad (B)$$

The following reaction has priority over the above reactions (A) and (B) in a small cluster in a metal.

$$2D + D \rightarrow {}^{4}He + d \qquad (C)$$

where recoil energy is shared by the deuterium d or cluster. Since the progress in reaction (C) calls for the nearby presence of the third deuterium as a prerequisite, it cannot be observed in the plasma phase.

Furthermore, in the cluster, the following many body fusion may be generated in addition to reaction (A).



etc.

γ-Ray Spectrum: The propriety of the Nattoh model can be reviewed by the observation of the reactive product material in the case of the reactions (A) to (M). Fortunately, Pons-Fleischmann[1] measured the γ-ray spectrum.

They explain the measured γ-ray spectrum as the absorbed γ rays of 2.45 MeV neutrons induced by H in a water bath, but their explanation is hard to believe, since the γ rays' intensity is quite weak.

In the Nattoh model, it was observed that the γ rays were emitted by the reactions (E), (G), and (K):

$$\begin{cases} {}^{6}Li^{*} : 2.185\ 3.562\ MeV \\ {}^{8}Be^{*} : 1.527\ 1.999\ 2.283\ MeV \\ {}^{10}B*^{*} : 2.15\ \ 2.87\ \ MeV \end{cases}$$

The author calculated the γ-ray spectrum based on the following equation:

$$H(E) = \Sigma\ Ai\ \exp\ (-(E-Ei)^{2}/\sigma^{2}) \qquad (1)$$

where σ stands for resolution.

Figure 1 shows the comparison between the result of our calculation and the measured values by Pons-Fleischmann.

The figure clearly indicates that the main peak of the γ rays is caused by the γ emitted from the $^{6}Li^{*}$ of 2.185 MeV. The lump located on the right side of the main peak is 2.283 MeV of γ ray emitted from the $^{8}Be^{*}$.

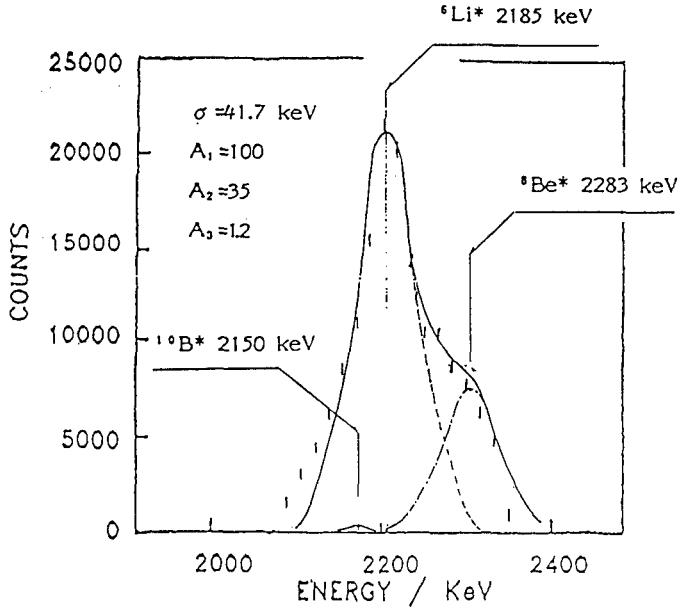


Figure 1.

However, we cannot observe the 2.15 MeV of γ rays emitted from $^{10}Be^*$ because of their weak intensity.

Neutrons discharged: It is recognized that two neutron discharge modes exist: intermittent and unexpected discharges.[3]

The Nattoh model rejects the idea that reactions (A) and (B) advance directly. However, it is expected that reactions (A) and (B) are produced indirectly, since the high energy deuterium d discharged as a result of reaction (C) collides with D in Pd-D. In that d has a maximum 16 MeV of recoil energy, the range in Pd-D is 0.02 cm and below, and the generation probability of reactions (A) and (B) is reduced by 10^{-4} to 10^{-6} compared with the reaction (C).

On the other hand, the many body-reactive product of $^8Be^*$ and $^{10}B^*$ has a neutron discharge channel.[4] The concentration of deuterium contained in a metal shows an exceptionally high value. When the concentration of deuterium in the cluster is increased, the probability of a many body-reaction will be increased accordingly. Therefore, the neutrons will be discharged unexpectedly. However, the energy of the neutrons at that time is not 2.45 MeV, but will be around 20 MeV [as published].

Distribution of reactive product: Since reaction (C) is a predominant reaction in terms of the Nattoh model, the production of ^4He shows the maximum value. Since reactions (A) and (B) are of an unexpected type, T, ^3He, and H are exceptionally small in quantity. Furthermore, ^6Li, ^7Li, and ^7Be are produced in small quantity due to the many body-reaction.

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Cross-Section of D-D Reaction Below 10 keV

906C0038L Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 p 25

[Article by Sadae Yamaguchi, Masayuki Hasegawa, Shinji Nagata, and Tsuyoshi Kajitani, Metallurgical Research Institute of Tohoku University]

[Text] Many verification and disproof tests of cold fusion have been conducted, and theoretical research to interpret experimental results has been reported. As causes of cold fusion, they advocate such mechanisms as the presence of compressed molecules with small atom-to-atom distances, an increase in Coulomb barrier transmittance, acceleration induced by high electric field gradient generated in a microcrack, or the like. To explain the experimental results based on these mechanisms, it is necessary to have the experimental data of the D-D nuclear fusion cross section in a low energy region. However, conventional measurement of the D-D fusion cross section is limited to the energy region of 15 keV and above. The low energy cross section can be obtained by extrapolation of the equation of Gamov from a high energy region.

It has recently been reported that the branch that generates tritium occurs with higher probability than the branch that generates neutrons in terms of cold D-D nuclear fusion,[1] and the $D(^3He, p)^4He$ reactive cross sectional area in a low energy region is increased by the shielding effect.[2] It is highly possible that these results suggest that the cross sectional area or the branch of the D-D nuclear fusion in the low energy region is markedly different from the extrapolated value in a high energy region. That is why we have conducted our research in an effort to study these possibilities.

Figure 1 shows the schematic view of our experimental device. The ion gun used in this experiment is a Colutron Co. made gun. It is designed to take out only D^+ or D_2 ions by a mass filter of E x B for injection. The acceleration voltage is variable from 10 V to 10 kV. The beam diameter is 3 mm, while the beam wave is 6 μA. The target is an 0.2 mm thick $TiD_{1.97}$ sheet generated by the reaction between the air phase and the solid phase, and is supported on a copper plate that allows atom motion and liquefied nitrogen cooling. Three types of charged particles produced by nuclear fusion (p, t, ^3He) were counted by a surface barrier type semiconductor detector. The deuterium particles scattered were removed by placing a 1 μm thick Mylar film at the front of the detector. The

energy of the charged particles of p, t, and ^{3}He generated by nuclear fusion reaction is E_p = 3.0 MeV, E_t = 1.0 MeV, and E_{3He} = 0.8 MeV, which are different from each other in their intensity, and allowed us to separate their respective charged particles easily for their counting.

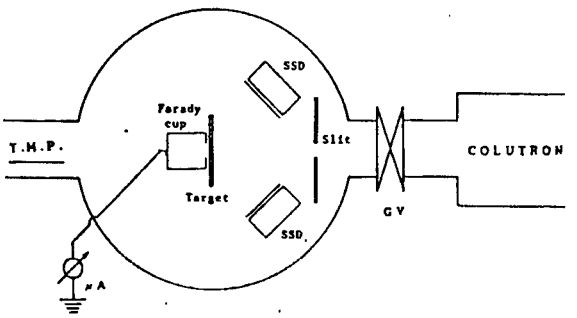

Figure 1. Schematic View of Experimental Device

The cross sectional area σ (E) can be obtained from the yield Y (E) per incident particle, using the following relational expression:

$$\sigma(E) = 1/N \cdot dY/dE \cdot dE/dX.$$

where N stands for the atomic density of d, and dE/dX for stopping power.

Since the fusion reaction yield is sharply decreased in proportion to the drop in the energy of incident particles, longer measurement time was called for as the energy is reduced.

We will report our experimental energy data in as wide a scope as possible in the meeting.

Acknowledgement: Concluding this article, the authors would like to express gratitude to Tohoku Electric Power Co. Inc. which has subsidized our research funds.

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Behavior of Deuterium

906C0038M Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 27-28

[Article by Tetsuji Noda, Masakazu Shinozuka, et al., Metallic Material Research Institute of Chikuba: "Deuterium in Pd Under D_2O Electrolysis With High Electric Currents and Under Pressurized D_2 Gas at Low Temperature"]

[Text] **1. Introduction**

It has already been indicated that Pd and Ti can be used as electrodes in heavy water electrolysis, or they may produce D-D fusion when they are exposed to pressurized deuterium. In this article, the authors will report their study of the behavior of deuterium contained in Pd under high electric current density electrolysis and high pressurized deuterium gas; this was carried out as a preliminary experiment in an effort to measure traces of neutrons.

2. Deuterium Electrolysis Experiment

2.1 Experiment Method

In this experiment, we tried to estimate the hydrogen pressure on the Pd surface under electrolysis by measuring electric resistance and the quantity of deuterium contained in the Pd, using a heating device. We used a 0.3 mm ϕ x 40 mm long, 80 percent cold-worked material and an annealed material at a temperature of 1473 K. The solution used in this experiment was 0.1 ND_2SO_4. We tried to obtain the differential electric resistance between the testpiece and a dummy material, based on a four-terminal method at a temperature of 273~278 K. The electrolysis current density ranged from 1~500 mA/cm^2. We measured the overvoltage of hydrogen under D_2 currents at a temperature of 278 and 298 K. As for the quantity of deuterium in the Pd, we carried out electrolysis based on a 3 mm ϕ testpiece, and directly collected the deuterium in glycerin at a temperature of 353 K immediately after the suspension of electrolysis. We then obtained the total content based on the desorption through vacuum heating using a manometer.

2.2 Experimental Results

The electric resistance was increased virtually, based on two stages in terms of electrolytic time. More specifically, the increment in the electric resistance was a parabola type up to about 1 $\mu\Omega$ cm. Then, the electric resistance was dramatically increased and remained fixed up to 10 $\mu\Omega$ cm, when an attempt was made to obtain the content of deuterium accompanied by the increase in the electric resistance. In the early stage of electrolysis, the relation ($\mu\Omega$cm/at%D to about 1) was established for the most part between the electric resistance and the solid solution deuterium quantity. On the final stage when the resistance was fixed, the average quantity of deuterium was about 70~80 at%. Judging from these relationships, it is assumed that the Pd is transferred from the α phase to the $\alpha + \beta$ phase accompanied by the heavy water electrolysis. When the electrolytic current was intensified, the deuterium absorption speed was increased and the absorption quantity was saturated in a shorter time. In an attempt to define the deuterium absorption requirements under electrolysis, we studied the surface deuterium pressure from the absorption speed and the hydrogen overload. If it is assumed that the deuterium absorption in the early stage is made by the deuterium rate determination, it will be possible to obtain the surface deuterium pressure from the deuterium diffusion speed. On the other hand, the surface deuterium pressure can be obtained, based on the assumption that the generation of deuterium gas from the hydrogen overvoltage and the surface adsorption reaction are balanced, respectively. Figure 1 shows the relationship between the surface deuterium pressure and the electrolytic current thus obtained. The hydrogen pressure obtained from diffusion is estimated to indicate an atmospheric pressure of 10,000 and above when the current density is 1 A/cm^2. The surface hydrogen pressure obtained from the overvoltage indicated a higher value of about four digits. Figure 2 shows the time change in the average deuterium content D/Pd at an electrolytic current density of 50 mA/cm^2. After about 50 hours, the average composition was virtually fixed, and indicated D/Pd = 0.7~0.8. This value was equivalent to the β and agreed with the X-ray diffraction results.

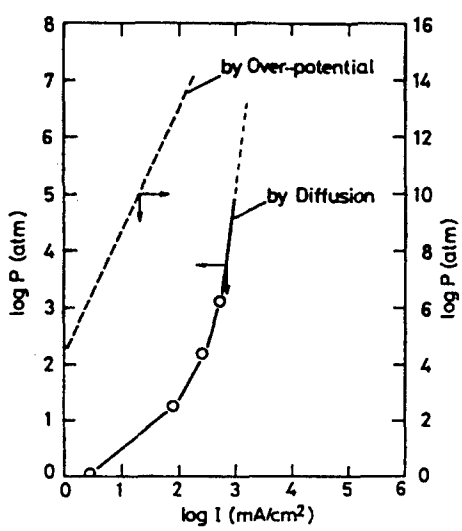

Figure 1. Relationship Between Surface Deuterium Pressure and Electrolytic Current

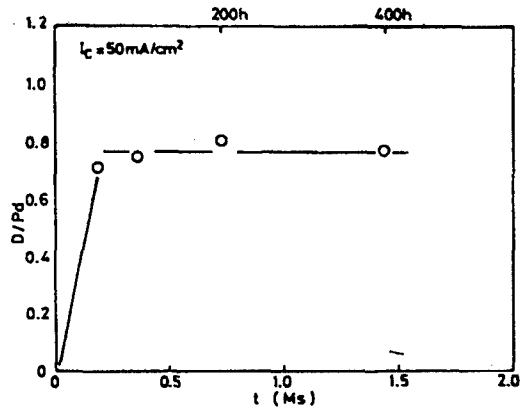

Figure 2. Time Change in Quantity in Deuterium Contained in Pd

3. Low-Temperature Pressurized Deuterium Gas Experiment

3.1 Experimental Method

In this experiment, we tried to study the behavior of deuterium contained in the Pd from the changes in the electric resistance under the pressurized deuterium. The sample used in this experiment was an 0.05 mm ϕ x 110 mm long small-sized wire. The deuterium pressure ranged from 0-90 atmospheric pressure. The temperature was changed from room temperature to liquefied nitrogen temperature. After the measurement vessel was vacuum-evacuated up to 1 Pa, the sample was cooled to the temperature of liquefied nitrogen. When the temperature of the sample was fixed, we tried to introduce deuterium gas into the measurement system, and measured the electric resistance, gradually increasing the temperature. After the experiment we identified the sample.

3.2 Results

Figure 3 shows the measurement result of the electric resistance of Pd line obtained by repeating the temperature rise and drop from the temperature of liquefied nitrogen to room temperature. As illustrated in the figure, the curve was gradually increased linearly in proportion to the rise in the temperature from the temperature of liquefied nitrogen. At a temperature of 0°C and higher, we observed a drastic rise in the resistance, which was attributed to the absorption of deuterium. The temperature at which the resistance rose dramatically was lowered as the pressure was increased. Figure 3 shows about 0°C at an atmospheric pressure of 16 and 20°C at an atmospheric pressure of 25. The composition balanced at room temperature was $PdD_{0.7}$, and virtually equivalent to a value expected from the pressure-composition state view of the Pd-D system. As indicated in Figure 3, once when deuterium was absorbed, the electric resistance varied reversibly with temperature change under deuterium gas.

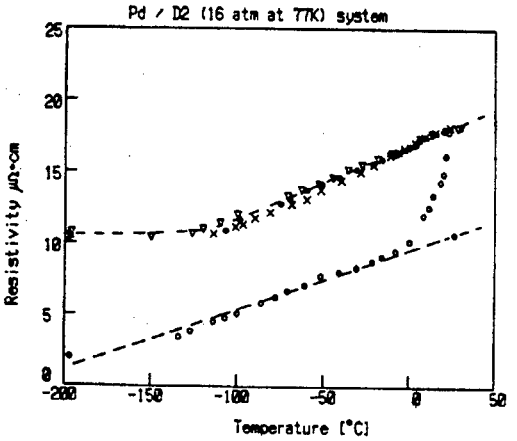

Figure 3. Relationship Between Electric Resistance of Pd in Pressurized Deuterium Gas and Temperature

4. Conclusion

We have drawn the following conclusion from the above experimental results:

(1) Under either high current density electrolysis at high pressure gas requirements, the behavior of deuterium contained in Pd does not deviate to a great extent, as indicated in the Pd-D state view.

(2) However, under the electrolytic requirement in this experiment, the Pd surface deuterium pressure was estimated to exceed at atmospheric pressure by several thousands.

(3) We find it necessary to study more carefully the deuterium state on the Pd surface under both the electrolysis and pressurized environments.

Future Prospects for Cold Fusion

906C0038N Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 pp 29-30

[Article by Kazuo Furukawa, Development Technology Research Institute of Tokai University: "Cold Nuclear Fusion: Future Scope"]

[Text] **1. Cold Nuclear Fusion Processes**

The history of the nuclear fusion research, which aims at the containment of plasma in pursuit of the Lawson criterion, has been filled with agony. After the war ended, the world powers attempted to develop DT fusion/fission hybrids as their highest confidential research in order to obtain fissile materials (FM). However, their confidential technologies were partly released to the public, since they lost their technological superiority over other methods, although some are still considered as military secrets. As clarified by Rose, Frass, and Carruthers in the 1960s, the first wall output density must be at least 10 MW/m^2 to put the leading magnetic field containment device to practical use. However, there still exist some obstacles to this development. (The concept of Li wall is excellent, but it is not considered a practical technology. Rather, the concept of molten salt may break the deadlock.)[1]

Under the situation stated above, is voiced the catalyzer nuclear fusion (μCF) where no plasma is adopted, in addition to the inertia nuclear fusion, which has brought about the recent situation in which various and unexceptional proposals have been made. The electrochemical approach is well known, and it is called ambient temperature (room temperature) nuclear fusion. However, the author would like to define it as cold temperature fusion, because it does not aim at plasma containment and is generally referred to as "no high temperature." Therefore, μCF is included.

2. Various Kinds of Cold Temperature Fusion

(A) μ Catalyzed Nuclear Fusion (μCF)

In the development of μ chemistry, we have succeeded in nuclear fusion by replacing the electrons of $(DT)^+$ ions with μ^- and turning dt distance into 1/200. (The experimental group leader in the United States is S.E. Jones.)

However, μ^- generated energy is huge in quantity, and the generated energy will not be applicable to practical use unless fission energy is obtained by producing FM with generated n. Furthermore, a huge amount of T must be provided at a very cold temperature.[2].

(B) Condensed Matter Nuclear Fusion (CMNF)

In 1986, S.E. Jones[3] indicated that we could reduce the internuclear distance based on the other method, say, at a very high temperature (the interior of the earth and celestial bodies) and produce d-d fusion to some extent. Although the nuclear fusion given in the next paragraph (C) was also conceivable, some groups, such as Frascati[4] or LANL detected nuclear burst by raising and dropping the temperature of a Ti hydrogen chemical compound which occludes D_2 pressurized at a low temperature. However, this mechanism is controversial (see paragraph (D)).

(C) Electrochemically Induced Nuclear Fusion (ECNF)

Jones[5] and Fleischmann[6] induced D to be occluded in Pd or Ti in an electrolytic manner, and strengthened the effect of ECNF by injecting D under the application of overvoltage. However, the phenomenon is sophisticated, so that the supplementary tests may be confused. The author finds it necessary to separate and define the phenomenon and mechanism. The author wonders if Fleischmann and Pons still conceal some experimental data? From the early stage, the research of ECNF reminded the author of the participation of cosmic rays.[7,8]

(D) Fracture Nuclear Fusion (FNF)

Based on the tradition of the electric and physical phenomena research of the solid fractured surfaces in the USSR from the 1970s, Klyuev[9] and his group fractured a 3~4 mm ϕ LiD monocrystal with an air gun bullet at a speed of 200 m/s and obtained about 10 n/shot. This is assumed to be the result of d-d nuclear fusion generated by the ion acceleration, based on the charge separation produced at cracks. Dickenson, et al.,[10] who have studied similar phenomena since 1980, conducted detailed research on $TiD_{0.8}$. They have already detected strong radiation, such as negative charge, positive ions, light, electrons, and radiowaves. They are reported to be extremely weak in terms of $TiH_{1.0}$, which may define and solve the mysterious parts of (BC).

3. Future Prospect

It seems to the author that we stand at a very interesting starting point. The situation is chaotic and further stimulative as well. As discussed in paragraph 1, there is no future prospect for the practical application of even dT nuclear fusion. Therefore, the application of $^3He \cdot D$ nuclear fusion based on ^3He available on the moon surface is even considered. The path toward the practical application still stretches a vast distance.[11] The author finds it necessary and valuable to extend and develop to the maximum the direction of the concept that the above low temperature suggests.[8] Table 1[8] shows some of the clues to the concept. We shall be very happy if an original experimental method can be created during their respective course of supplement and rearrangement.

Table 1. Various Elements and Factors Associated With "Low Temperature" Nuclear Fusion (Tentative)

Elements		Morphology, state
Reacting body	p^+, $H^{o,-}$ d^+, $D^{o,-}$ t^+, $T^{o,-}$ ^3He	Ion, atom, nucleus, microcluster, plasma, — Gas phase, liquid phase (surface, bulk, ——. aqueous solution, molten salt, ——) Solid phase (surface, interface, bulk, channel, defect, ——)
	α^{++}, ^4He ^6Li, ^7Li ^9Be, ^{10}B —	Capacity, mass, hours Pressure, temperature, stress—electromagnetic field, gravitational field, —— Electrolytic operation, corpuscular radiation/electromagnetic wave irradiation, shock damage, ——
	—	Equilibrium process, nonequalibrum process, ——
	Impurity nucleus ——	Steady phenomenon, nonsteady phenomenon, ——
Medium	—— n, γ, x e^-, e^+ μ^-, μ^+	<u>Reaction results (quantity and energy level)</u> Nucleation, compound formation, —— Radiative emission (n, γ, x, e, e^+, p^+, d^+, α^{++}, —)
	(cosmic) —— ——	Electromagnetic wave generation, emission, —— Heat generation (nuclear chemical reaction, nuclear transition, stress change, chemical reaction, kinetic energy change, ——)
	Pd, Ti, - Other metals,— Hydride, — Ionizable crystal, —— ——	<u>Purpose</u> For heating For n usage (production of nuclear materials) For γ usage

Concluding this article, the author would like to give a few comments:

(1) Thoroughly free thinking is called for in either case!

(2) However, excessive free thinking may be out of focus in a way. Many dreams to "practical application" would be wonderful and serve as an intellectual stimulant. A reverse idea may be acceptable from the standpoint of economic efficiency to be secured in a broad sense.

(3) Nuclear fission is the best (200 MeV) as an effective means to obtain energy. Even DT nuclear fusion can produce only one-tenth the energy (about 20 MeV). Therefore, FM production based on the application of n may be the most favorite energy source (see paragraph (A)).

(4) The application of heat may not be as effective as anticipated due to its "low temperature." However, the application of n may provoke nuclear proliferation or nuclear terrorism to which strict surveillance should be given.[7]

(5) The problems are further associated with the materials and chemistry in a broader sense. To begin with, the research and development of nuclear energy hangs low, which is attributed to chemistry's lagged participation.[1]

(6) What is called for is not a simple conception, but a synergetic conception based on various systems and concepts.[12] The author wondered whether it may assist with the conception of Th molten salt furnace.[13]

Acknowledgement. The author would like to express his thanks to many friends. The author has obtained information about Dickenson from Kunio Ozawa.

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Cold Fusion Detector

906C00380 Tokyo NIHON GENSHIRYOKU GAKKAI (1989 AKI NO TAIKAI) in Japanese Sep 89 p 282

[Article by Kazuyuki Watanabe, Hiroshi Sekimoto, Reactor Research Institute of Tokyo Industrial University, and Lee Daewan, Pusan University: "Investigation of the Detection Apparatus for Cold Fusion Neutron, Using NE213 Scintillator"]

[Text] **Introduction**

This spring, two groups reported experimental results that suggest the possibility of fusion reaction at room temperature. Since then, our groups also started investigation into the possibility. The detection of neutrons generated by fusion reaction is very important for verifying the nuclear fusion reaction. In the report[1] made by S.E. Jones, et al., the percentage of neutrons generated by the d-d nuclear fusion reaction is evaluated to be 0.41 (3/s). To detect such rare neutrons, it is necessary to design a detector that has a high detection efficiency and reduces background noise. Therefore, in this research, we designed a new organic liquid scintillator NE213 as a neutron detector, and could survey proper sizes and configurations with the higher detection efficiency and the minimum noise.

Method. The application of the Monte Carlo method is required for accurately analyzing sophisticated configurations, but in this research, we devised a cylinder that is simple in shape and identical in diameter and height to make a rough and analytical calculation in terms of the optimum dimensions.

We have conducted our analysis based on the following assumptions:

1. The neutrons generated by nuclear fusion reaction are a discrete source.

2. The neutrons generated by cosmic rays are attributed to background. The spectra are based on the data given in reference (2). Furthermore, they are assumed to be a parallel beam that falls directly on a plane of a cylinder.

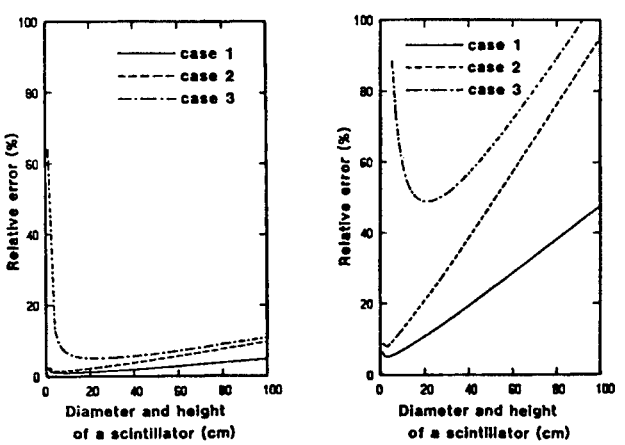
We made an analytical computation about detection efficiency, using the diameter (height) of the scintillator as a parameter in terms of the neutrons generated and the background. Based on this detection efficiency, we calculated the total count of the foreground and background. Furthermore, from the foreground and background, we tried to obtain the count of neutrons induced by the fusion reaction to be observed and the relative error. We used this error as a criterion to our judgment of the optimization.

Results: With regard to the position of neutrons generated by nuclear fusion, we assumed the following three cases:

Case 1: The center of the cylinder.

Case 2: The center of the upper plane of the cylinder.

Case 3: The point 5 cm above the upper plane of the cylinder.



(a) Generation rate of neutrons 0.41 (1/s)

(b) Generation rate of neutrons

Figure 1. Relative Errors of Detected Number of Neutrons Generated by Nuclear Fusion

Both Case 1 and Case 2 are assumed, based on a well-type scintillator. The measurement time is defined as 1 day. The percentage of neutrons generated by nuclear fusion is assumed to be 0.41 (3/s) and one-tenth of this value, respectively. Figure 1 shows the results of our measurement. In Case 1 and Case 2, the optimized value was available in a few cm. When the well-type configuration is considered, it will be practically difficult to attain the above value. However, the results of our measurement indicate that there exists an optimum size, even in the case of the well-type scintillator, although this value must be assumed to be very small. In Case 3, the optimum size is around 20 cm. In addition, it is realized that the well-type scintillator is absolutely predominant to minimize relative error. However, if the generation rate of neutrons is around 0.41 (3/s), it is believed that even

the cylinder type scintillator will be capable of reducing the relative error to a satisfactory extent, thereby enabling the detection of neutrons.

In the future, we are scheduled to more accurately analyze more sophisticated configurations, using the Monte Carlo method.

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